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STRATIGRAPHY, PETROGRAPHIC STUDIES, ALTERATION, AND GEOCHEMISTRY AT THE RAILROAD DISTRICT, ELKO COUNTY, NEVADA

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INTRODUCTION

The Railroad District, also known as the Bullion District, is located in the northern Piñon Range, approximately 15 miles south-southeast of Carlin, Nevada, within the southern extension of the Carlin Trend (Figure 1) (Dean, 1991). Historically, the Railroad District has been a producer of copper-lead-silver-zinc ore from replacement and skarn deposits, as well as barite from veins, and minor lode gold from quartz-gold veins (Gillerman, 1982). During the 1980s, a sedimentary-rock-hosted, disseminated gold deposit was delineated, due to extensive exploratory drilling within the altered and mineralized areas of the Railroad District (Figure 2). The Railroad gold deposit, which has a 4000 by 6000 foot oval-shape, is reported to contain 1.5 million tons of ore averaging 0.08 ounces of gold per ton (LaPointe et al., 1991).

GEOLOGIC BACKGROUND OF THE DISTRICT

Units exposed within the Railroad District include Paleozoic sedimentary rocks, middle Tertiary intrusive rocks, Tertiary volcanic rocks, and Quaternary deposits (Figure 3). The Ordovician sedimentary rock units that have been mapped within the district include the Pogonip Group, the Eureka Quartzite, and the Hanson Creek Formation. These units are exposed within the eastern portion of the district, along with the Silurian Lone Mountain Dolomite. The Nevada Formation and the Devils Gate Limestone have been mapped as the Devonian units that are exposed as a centrally located, northeast- to southwest-trending band within the district (Ketner and Smith, 1963). Nomenclature and definition of the Mississippian units are not as clear-cut as those of the other Paleozoic

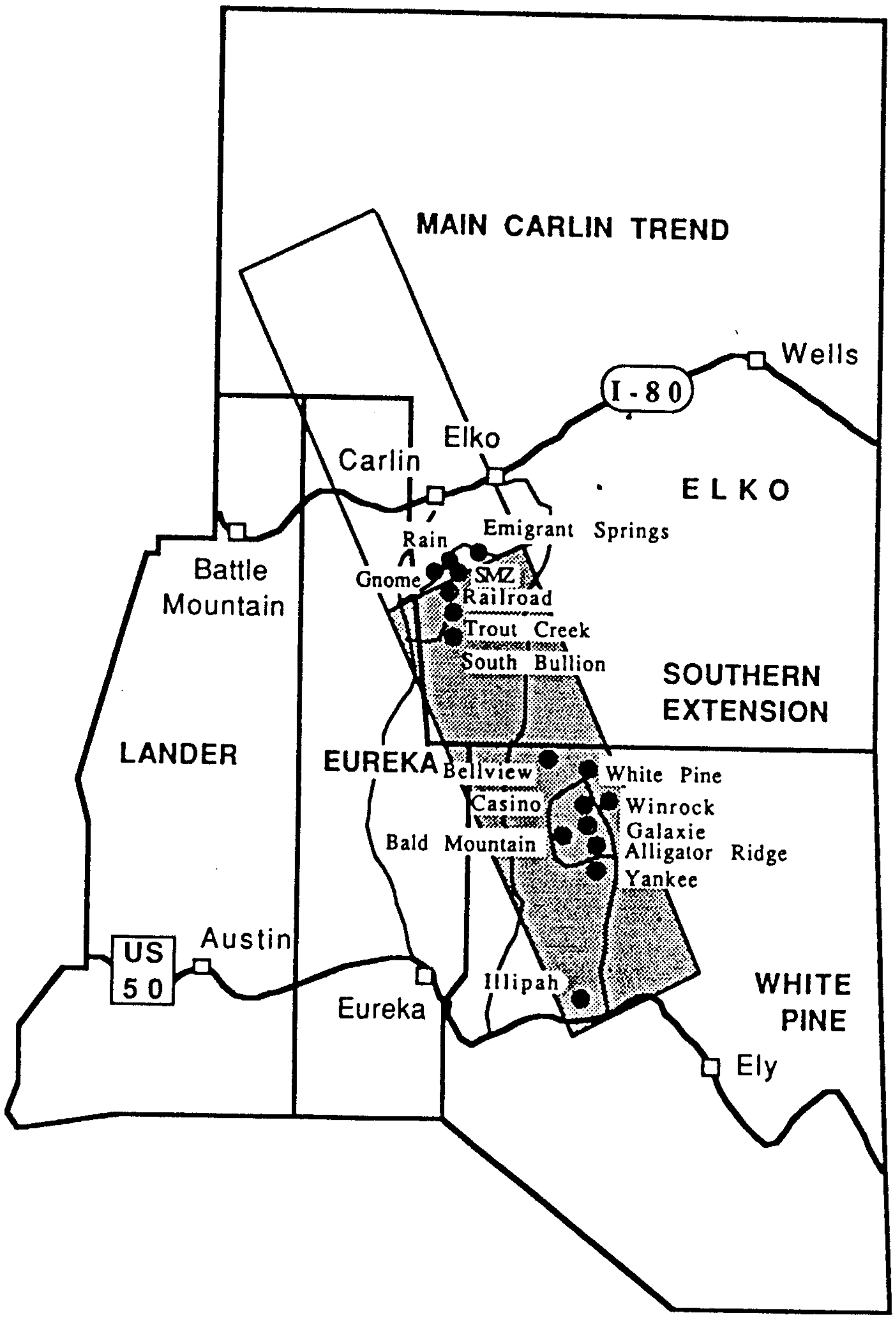

Figure 1. Location map for the Railroad District, and its position within the southern extension of the Carlin Trend (Dean, 1991).

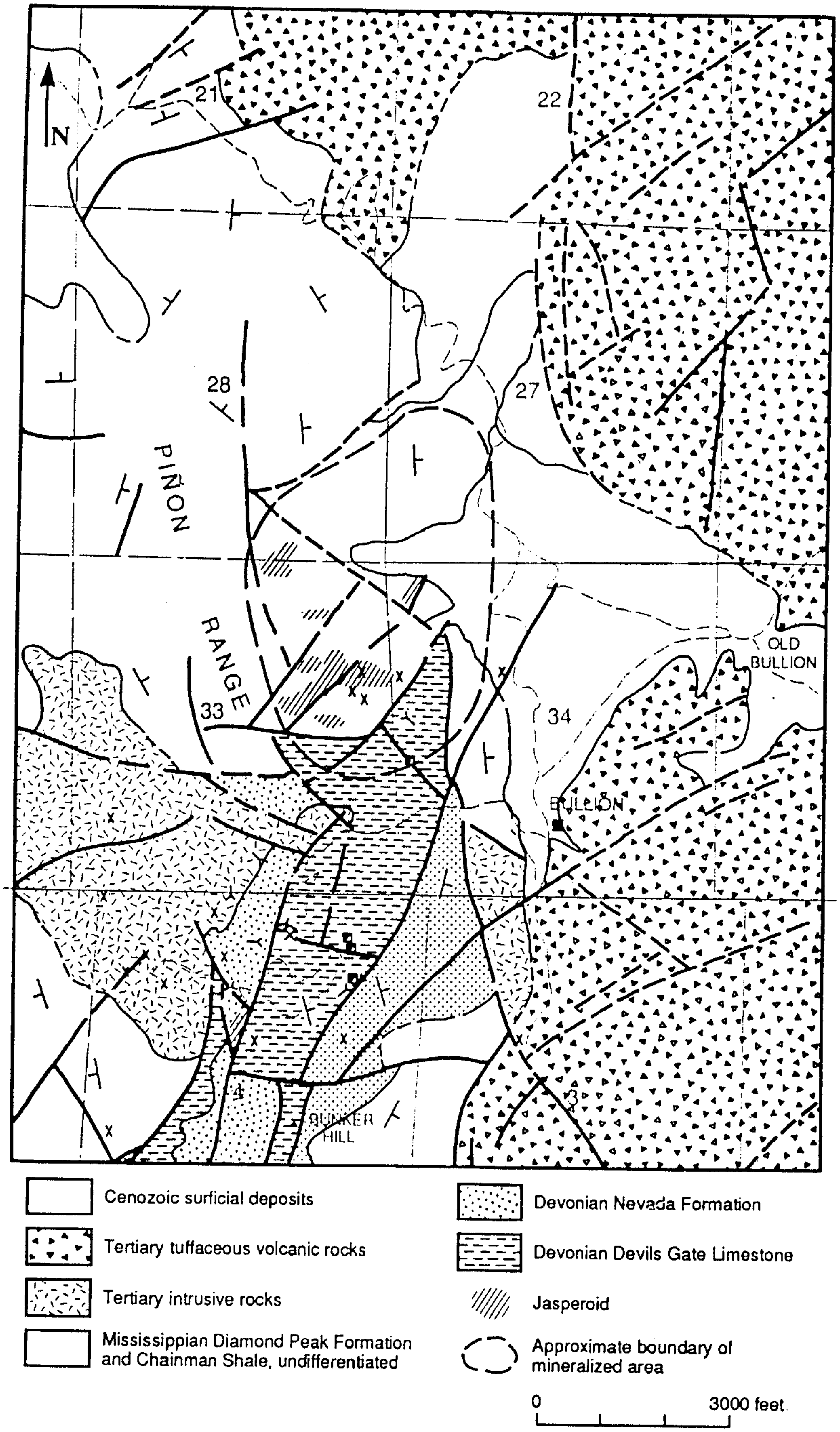

Figure 2. Generalized geologic map of the Railroad gold deposit, Railroad district (LaPointe et al., 1991; modified from Dean et al., 1990).

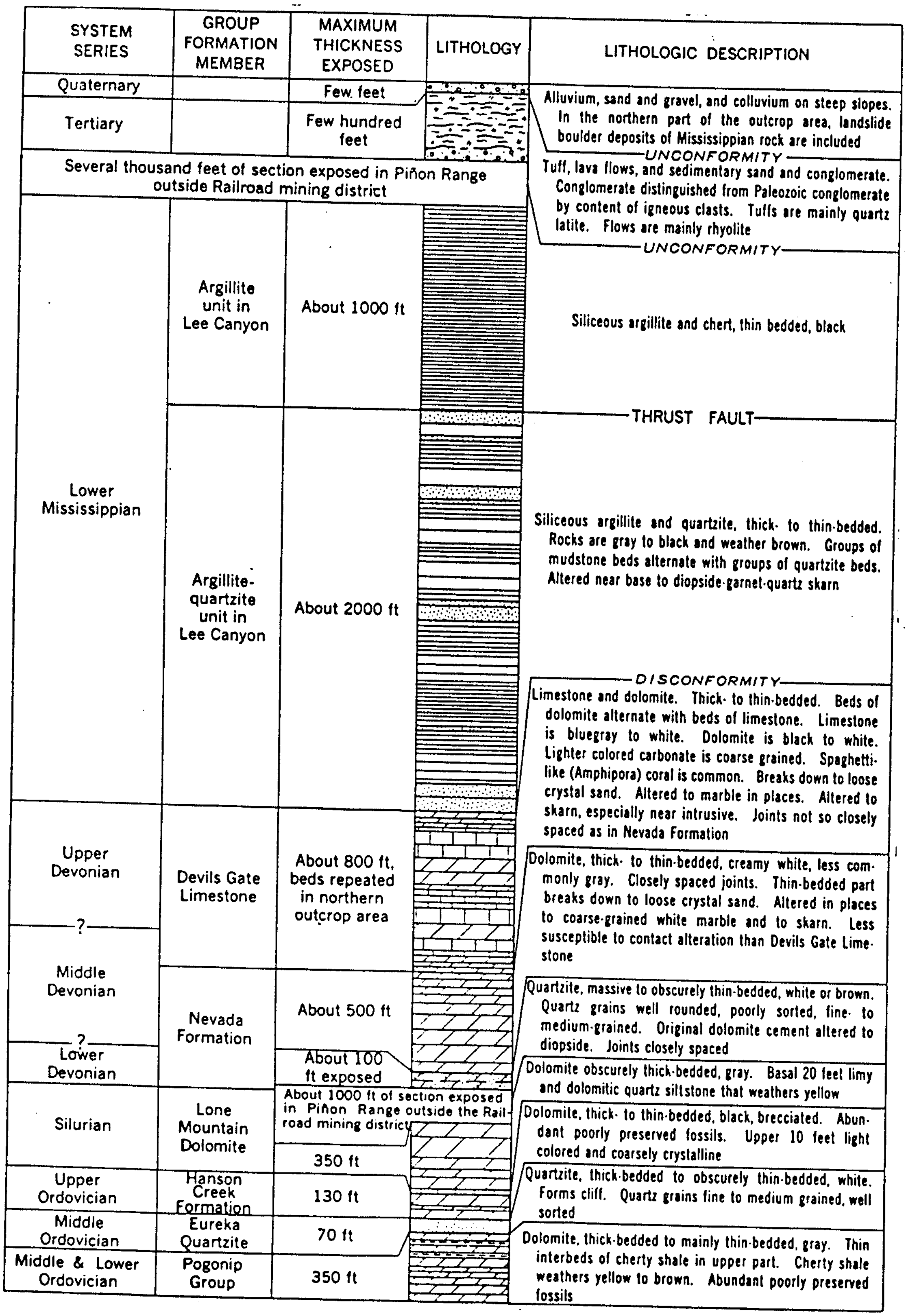

Figure 3. Stratigraphic column of rocks exposed in the Railroad mining district, Nevada (Ketner and Smith, 1963).

units exposed at Railroad. The Mississippian exposures have been described as a lower argillite-quartzite unit in Lee Canyon, and an upper argillite unit in Lee Canyon by Ketner and Smith (1963). Lee Canyon is an east-west trending canyon that is located within the district. Smith and Ketner (1975) later correlated the argillite-quartzite unit with the Mississippian Chainman Shale. Gillerman (1982) split the Mississippian rocks at Railroad into lithologic units including argillite, argillite-quartzite, and undifferentiated quartzite, argillite, conglomerate, chert, and shale. The Mississippian rocks have also been mapped as undifferentiated Diamond Peak Formation and Chainman Shale (Coats, 1987; LaPointe et al., 1991). During the early 1990s, detailed mapping of the district was completed by Exploration Mirandor. As a result of this recent endeavor, the Mississippian rocks were split into many separate lithologic units that were designated as parts of the Chainman Formation (Will Nordquist, Exploration Mirandor, personal communication, 1998).

Middle Tertiary rocks that intrude the Paleozoic package include a stock of granite, monzonite, quartz monzonite, quartz diorite, and rhyolite porphyry, and associated rhyolite porphyry dikes. The Bullion stock consists of an outer shell of granite, quartz diorite, and monzonite that surrounds an inner core of rhyolite porphyry (Ketner and Smith, 1963). The age of the stock has been determined by K-Ar dating methods. The dates determined include: 35.4 ± 1.1 m.y. from feldspar from the granitic shell, 36 ± 1.4 m.y. from the whole rock rhyolite porphyry (Coats, 1987), and 33 Ma from a biotite crystal from the quartz monzonite. The core of the stock is located approximately 4000 feet southwest of the Railroad gold deposit. (LaPointe et al., 1991). Numerous rhyolite porphyry dikes cut the Paleozoic units throughout the central portion of the district.

Overlying the Paleozoic rocks with significant unconformity are several hundred feet of Tertiary quartz latite tuffs and rhyolite flows. These rocks are exposed within the eastern portion of the Railroad district, and east and north of the Railroad gold deposit (Ketner and Smith, 1963).

Quaternary cover includes alluvium, sand, gravel, colluvium, and landslide deposits. This cover extends from north to south in the eastern portion of the district, including within the gold deposit area. These deposits have a thickness of a few feet (Ketner and Smith, 1963).

The sedimentary rocks have been folded into the overturned, north-trending Piñon Range anticline, whose axis is located west of Bunker Hill. Since the Piñon Range is symmetrical and is not faulted continuously on either side, it has been interpreted as being the physiographical expression of the anticline, rather than a fault block. The plutonic rocks intrude the central portion of the anticline, and several high angle normal and reverse faults cut the anticline (Ketner and Smith, 1963). The disseminated gold of the Railroad deposit is hosted by the basal silicified sedimentary rocks of the undivided Mississippian units. Mineralization is thought to be strongly dependent on structural control, though locally the gold mineralization penetrates into adjacent favorable strata (LaPointe et al., 1991).

GOALS AND SCOPE OF THIS STUDY

There are several goals of this diverse project. The primary goal is to complete outcrop-style geologic mapping in the vicinity of the Railroad gold deposit. Since outcrop exposure is limited and there are no continuous marker beds within the study area, mapping was done on the basis of lithology, rather than on the basis of formational names. Examination of representative outcrop samples in thin section was completed in order to understand the lithologic differences of the rocks being studied. Other goals of the project are to define the structure of the study area, and to attempt to date the rock units by biostratigraphic methods.

Additional goals of the project include the mapping of and characterization of alteration zones within the map area. Also, this study will involve analysis of geochemical data provided by Kinross Gold. Oxygen and sulfur isotope data from barite samples collected from several areas within the map area will be interpreted.

FIELD METHODS

Mapping and sampling were completed during the summer months of 1998. The study is concentrated on the immediate vicinity of the Railroad gold deposit, which is located at the eastern face of Bald Mountain (Figure 4). Outcrops within an area of approximately 2 square miles were mapped by lithology, at a 1:6000 scale. Standard traverse mapping with a topographic base map and aerial photographs was completed. Approximately 250 rock samples were collected. Sixty-one of these were used to make thin sections and thirty-one of these were rhyolite porphyry intrusive samples that were used for geochemical analysis. Fourteen samples were collected for barite isotope analysis, and seven samples were collected for use in biostratigraphic studies.

LITHOLOGY

The following lithologic descriptions are based on field occurrences, and hand sample and petrographic examinations.

Tertiary Volcanic Rocks

Tertiary volcanic rocks are present at the easternmost edge of the study area, although there are no outcrop exposures of these rocks (Figure 4). The samples that were examined megascopically and petrographically were collected from float. These volcanic rocks are aphanitic-porphyritic, holocrystalline, and leucocratic, with a composition ranging from dacite to andesite. They have a tan groundmass with 0.5 mm to 1.5 mm subhedral to euhedral phenocrysts of biotite, resorbed quartz, and subhedral plagioclase feldspar. There is weak argillization (sericite + illite + kaolinite) of the plagioclase, especially on grain boundaries and within fractures. No other alteration of the volcanic rocks was observed.

Tertiary Intrusive Rocks

The Bullion stock is exposed in outcrop at the southwestern boundary of the study area (Figure 4). It is a zoned intrusive body, with a core of rhyolite porphyry and an outer shell with a composition ranging from granite to quartz monzonite, monzonite, quartz diorite, and granodiorite (Coats, 1987; Gillerman, 1975). Only the outer shell type rocks are present within the boundaries of the map area. The samples that were collected and examined are hypidiomorphic, granular, phaneritic, and locally porphyritic with a

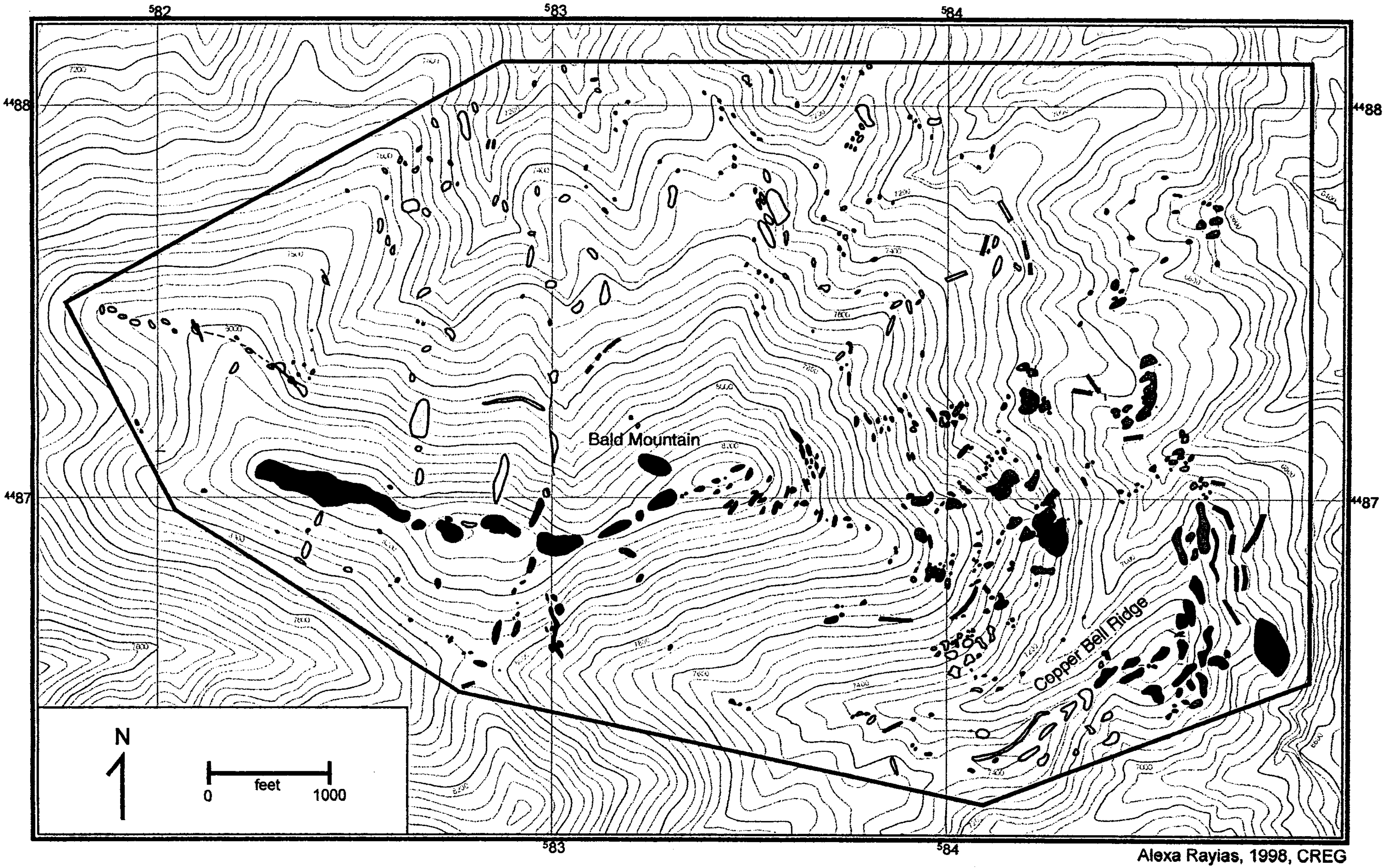

Figure 4. Geologic map of the study area within the Railroad district. Map explanation is on the following page.

EXPLANATION OF MAP UNITS IN FIGURE 4

Tertiary granodiorite of the Bullion stock

Tertiary rhyolite porphyry dikes and sills

Mississippian impure siltstone, sandstone, and granule conglomerate

Mississippian light to medium gray siltstone, sandstone, and conglomerate

Mississippian white siltstone, quartzite, and associated conglomerate

Mississippian gray sandstone to pebbly sandstone

Mississippian laminated dark gray argillite

Devonian limestone (Devils Gate and/or Nevada Formation)

Devonian dolostone (Devils Gate and/or Nevada Formation)

Marble

Skarn

Jasperoid

granodioritic composition. The rock consists of plagioclase, quartz, alkali feldspar, and biotite. The anhedral to subhedral quartz and feldspar crystals are up to 3mm; the biotite is present as platy books that range from 0.8 mm to 2.0 mm. Sericite locally replaces the feldspar crystals along lattice planes and grain boundaries. Sparse, thin (0.01 mm to 0.03 mm) veinlets of limonite locally cut the granodiorite. No other alteration within this rock type is apparent.

Exposures of the rhyolite intrusive rocks are present throughout the study area, primarily in road cuts or in some cases as high relief outcrops that blaze across the hillside (Figure 4). These rocks occur as dikes that cut across the clastic and carbonate rocks or as sills. Most of the rhyolite intrusive rocks are porphyritic; however, some are aphanitic. The implications of these textural variations are unclear. Either the dikes are texturally zoned, or they represent different pulses of igneous activity. The white rhyolite porphyritic rocks consist of an aphanitic groundmass of quartz and feldspar with phenocrysts of subhedral to euhedral feldspar crystals and resorbed quartz. The phenocrysts range in size from 0.5 mm to 3 mm. Euhedral to subhedral zircon crystals are present in most samples; tabular apatite crystals are present in several samples. The non-porphyritic rhyolite intrusive rocks are aphanitic with a hypidiomorphic texture of quartz and feldspar. Both the aphanitic and aphanitic-porphyritic rhyolites commonly contain small cubes (0.001 mm to 0.3 mm) of hematite or goethite as pseudomorphs after pyrite. In all of the samples that were examined both megascopically and petrographically, the feldspars are almost completely argillically altered to sericite, illite, kaolinite, and smectite. Thin veinlets (0.006 mm to 0.1 mm) of limonite or barite are locally present.

Clastic Rocks

The clastic rocks at Railroad, which are presumed to be and have been previously mapped as Mississippian, range in grain size from claystones to conglomerates. Several lithologic units are defined on the basis of field relations, megascopic description, and petrographic description. Due to the erratic and limited exposure of these units, and the generally discontinuous and lenticular nature of these rocks, simplifications such as grouping similar units (rather than splitting out units with the slightest change in lithology) have been necessary. Thus, only those units with a clear, distinct, and continuous lithology are divided here. Since the formation to which these rocks should be assigned is unclear (Chainman or Webb), the rocks will be designated by lithologic classification. The age relations between these units has not been determined.

Impure Siltstone, Sandstone, and Granule Conglomerate

Impure, gray to black, clastic rocks are exposed at the southeastern portion of the study area, on the eastern side of Copper Bell Ridge (Figure 4). These rocks include siltstone, silty sandstone, pebbly sandstone, and granule conglomerate. The siltstones contain quartz and very fine-grained clay minerals. The gray sandstones are quartz wackes to arkosic wackes, with a mineralogy of monocrystalline quartz, feldspar, hematite, goethite pseudomorphs after pyrite cubes, and white mica or illite. The grain size ranges from coarse silt- to medium sand-sized. Quartz and feldspar grains are moderately sorted to well sorted, subrounded, and have a moderate sphericity. The matrix consists of silt and clay minerals.

The granule conglomerates are interbedded with the finer grained rocks that are discussed above. They are dark gray and contain clasts of quartz and lithic fragments; the rock fragments include quartz arenites, quartz wackes, and gray to black cherts. These rocks are both clast and matrix supported, and generally have less matrix than other conglomerates in the study area. The granule-sized clasts are well sorted, subrounded, and have a low sphericity.

The rocks of this type are exposed in several fairly resistant outcrops, and in the road cuts on the eastern side of Copper Bell Ridge. They are massive to thick-bedded.

Light to Medium Gray Siltstone, Sandstone, and Conglomerate

Light to medium gray siltstone, sandstone, and conglomerate are exposed on the lower to upper slopes of the eastern face of Bald Mountain (Figure 5). These units are lenticular to interbedded; beds or lenses of these rocks range from two to twenty-five feet thick. The sandstones, which are predominantly quartz wackes, have the most abundant and continuous exposure.

The siltstones of this unit consist of very fine silt- to coarse silt-sized grains of quartz and clay minerals. They are light gray to tan; the siltstones weather brown and have an affinity for iron oxide stains on the surface and in fractures. These tend to be slope formers, with low relief exposures and sub-outcrops.

The gray quartz wacke sandstones consist of fine to medium sand-sized grains of monocrystalline quartz. These grains are subangular to subrounded, moderately to well sorted, and have moderate sphericity. Between fifteen and twenty percent of the composition of the wackes is a matrix of limonite, illite, and smectite clays. Locally, microscopic orpiment (up to 3%) is present as veinlets and disseminated subhedral crystals within the sandstones. Also, barite veinlets (0.05 mm to 0.5 cm) locally cut these rocks. The wackes tend to weather brown, and iron oxide surface staining is common. These rocks form sub-outcrops to generally prominent, moderate relief outcrops.

Interbedded and lenticular within the sandstones are pebbly sandstones and pebble to cobble conglomerates. These rocks are matrix supported, and have well rounded clasts of white quartzite, gray siltstone, and gray, white, and black chert. They are not imbricated.

White Siltstone, Quartzite, and Associated Conglomerate

Outcrops of buff to white siltstone, white quartzite, and associated conglomeratic intervals are exposed on the southwestern slope and on the top of Bald Mountain (Figure 4). These units appear to be interbedded to lenticular, and the white quartzite is the exposed more continuously than the siltstone and conglomerate.

The buff to white siltstone is comprised of clay- to very fine silt-sized grains of quartz and clay minerals. It tends to weather brown and commonly has strong iron oxide staining on the surface and in fractures. The siltstone is well exposed in roadcuts, and in several highly fractured, low relief outcrops near the top of Bald Mountain. Abundant sharp-edged, blocky-fractured talus litters the hillside below and in the vicinity of these outcrops. The siltstone is also present as interbeds within the associated white quartzite.

The white quartzite is comprised of very fine sand- to medium sand-sized quartz grains that are moderately to well rounded, well sorted, and have moderate sphericity. It generally contains less than 15% matrix of clay minerals. Bedding is massive to obscure. This unit also tends to weather to a medium brown color, and has iron oxide staining. Outcrops of this unit tend to be small and of low relief. Barite veining is common throughout the quartzite, especially at the southwestern portion of the study area. Sparse subhedral, microscopic orpiment crystals are scattered in the quartzite locally.

The conglomerate that is associated with this package of rocks consists of pebble to cobble sized clasts of white and gray quartzite, and white, gray, and black chert. The clasts are well rounded, non-spherical, and non-imbricated. Silty to sandy matrix supports the clasts. These conglomerates are best exposed near and on the top of Bald Mountain.

Gray Sandstone to Pebbly Sandstone

Interbedded gray fine-grained to coarse-grained sandstone and pebbly gray sandstone are exposed on the northern side of Bald Mountain (Figure 4). These sandstones are made up of gray quartz grains and gray, black, white, and uncommon green chert fragments. The sandstone grains are subangular to subrounded, moderately sorted, and have low to moderate sphericity. Clay mineral matrix is present in quantities up to 22%. Thin barite veins are present locally, but they are not common. These rocks are massive to obscurely bedded. Outcrops are best exposed in drainages.

Laminated Dark Gray Argillite

Dark gray argillite is exposed in small, low relief outcrops on the western side of the top of Bald Mountain (Figure 4). It is laminated with alternating bands (1 mm to 2 cm thick) of medium and dark gray argillite. Due to the extremely fine-grained nature of this rock, no thin sections were examined. However, the primary constituent appears to be gray quartz. Clay minerals are also likely present.

Carbonate Rocks of the Devils Gate and Nevada Formations

Limestone, dolostone, and marble of the Devils Gate and Nevada Formations are present along the southern and eastern edges of the study area, specifically on Copper Bell Ridge and on the southern and eastern faces of Bald Mountain (Figure 4). However, the carbonate rocks within the eastern portion of the map area are dominantly silicified. These jasperoids will be described in a section to follow. Locally, the carbonate rocks have been altered to skarn. These skarns will also be discussed in a later section.

The carbonate rocks that were examined during this study have been previously mapped as the Devonian Devils Gate and Nevada Formations (Ketner and Smith, 1963). However, since these rocks are recrystallized and marbleized where the contact between them has previously been mapped, it is extremely difficult to differentiate the two formations here upon field examination. Therefore, on the maps that accompany this report, the carbonate rocks will be split up into the lithologic units of limestone, dolostone, and marble.

The limestone and dolostone at Railroad is a medium brownish gray to black sparite, micrite, or dolomite. These carbonate rocks are thick to massive bedded, with localized intervals that contain plentiful light gray and white, dolomite and sparry calcite, tubular-shaped *Amphipora rugosa* fossils. Intervals with interbedded fine-grained clastic rocks are present locally on the low slopes of the eastern face of Bald Mountain. These interbedded silty intervals, some which are calcareous, contain discontinuous or lenticular fine-grained sandy beds.

Anastamosing, cross-cutting veins and veinlets of calcite that range from 0.05 mm to greater than 5 cm in width are ubiquitous within the limestone and dolostone exposures. Cross-cutting barite veins and veinlets are abundant within the limestones and dolostones at Copper Bell Ridge. These white barite veins range from 0.03 mm to 1 m in width. Subhedral, clotty and disseminated goethite and hematite grains are dispersed throughout many of the limestones and dolostones.

Locally, the carbonate rocks within the study area are recrystallized to a light gray or white marble. This marble is coarse-grained, with subhedral to euhedral calcite crystals up to 8 mm. The marble also contains subhedral to euhedral cubes of hematite, as pseudomorphs after pyrite.

Skarn

Skarn is present near and at the contact between the granodioritic Bullion Stock and the carbonate rocks of the Devils Gate and Nevada Formations (Figure 4). It is exposed as several small outcrops in trenches that are cut near this contact. The rocks are dense and massive. The skarn consists of grossular garnet, tremolite, wollastonite, and calcite, with local occurrences of grossularite which is primarily composed of grossular garnet (>90%). Megascopically, the skarn is aphanitic and tan, with small rosettes of tremolite and wollastonite. Along fractures, the grossular garnet has been hydrated to form euhedral, zoned hydrogrossular garnet. Quartz and chalcedony veinlets are sparse, but present, within some skarn samples. Hematite is present throughout the skarns as disseminated and clotty subhedral clumps, with individual grains ranging from 0.003 mm to 0.02 mm.

Jasperoids

Silicified rocks are locally abundant at Railroad, particularly on the eastern face of Bald Mountain (Figure 4). These jasperoids are silicified, highly resistant, and prominent bodies. Megascopically, the jasperoids are aphanitic, medium to dark gray, brown to orange weathering, commonly brecciated rocks with a uniform texture. They are cut by veins and veinlets of quartz, barite, hematite, jarosite, and goethite that range from 0.002 mm to 3 cm in width.

When examined petrographically, a variety of textures within these seemingly non-descript rocks becomes apparent. The silicification products range from the common jigsaw and xenomorphic textured quartz to the less common reticulate textured quartz and chalcedonic spherules. Localized patches of very fine-grained to coarse-grained (0.001 mm to 1.5 mm) quartz are optically continuous. The very fine-grained quartz is much more common than the coarser grained type. Very small (0.001 mm to 0.01 mm), rounded to oval patches of calcite are present as inclusions within the quartz in most of the jasperoid samples that were examined. These patches have been interpreted to be remnants of calcite leftover from a calcite-bearing protolith. From petrographic examination only, it is unclear whether the protolith(s) for these jasperoids was (were) limestones, dolostones, or calcareous siltstones. The preliminary interpretation of the author, however, is that these jasperoids are likely to be silicified limestones and dolostones rather than siltstones. More on this issue will be discussed in a later section.

All of the jasperoid samples that were examined contain limonite staining and pseudomorphs after pyrite, locally up to 45%. Goethite and hematite are dominant, but local jarosite is present. Several jasperoid samples that were observed in thin section contain up to 4% orpiment. In many of the jasperoid samples, barite is present as veinlets or vug-fill.

STRUCTURE

The structural relations at Railroad are complex, and the lack of abundant outcrop exposure hinders one's ability to make good structural interpretations. Structural interpretations are made based on field occurrences and observations and drill log data. Drill logs from past drilling activity have been made available by Exploration Mirandor. After closer examination of these logs, more detailed (and less preliminary) structural interpretations will be made.

Bedding Orientations

Many of the exposures at Railroad are of massive or obscurely bedded rocks. Bedding attitudes were measured only if they could be measured with the confidence that they were actually bedding planes. Seventy-eight bedding attitudes were measured throughout the map area. These were plotted on a stereonet (Figure 5a). Unfortunately, the attitudes are so varied that it is difficult to make a sound structural interpretation based on Figure 5a. Therefore, the field area was split into five structural domains, in an effort to better understand each (Figure 6).

The first domain is in the vicinity of the Bald Mountain Fault; this domain includes ten bedding attitudes. The stereonet upon which these have been plotted is included in Figure 5b. Although there is scatter within this plot, it is evident that the bedding dips are generally shallow and to the northwest, and that the beds strike moderately to the northeast.

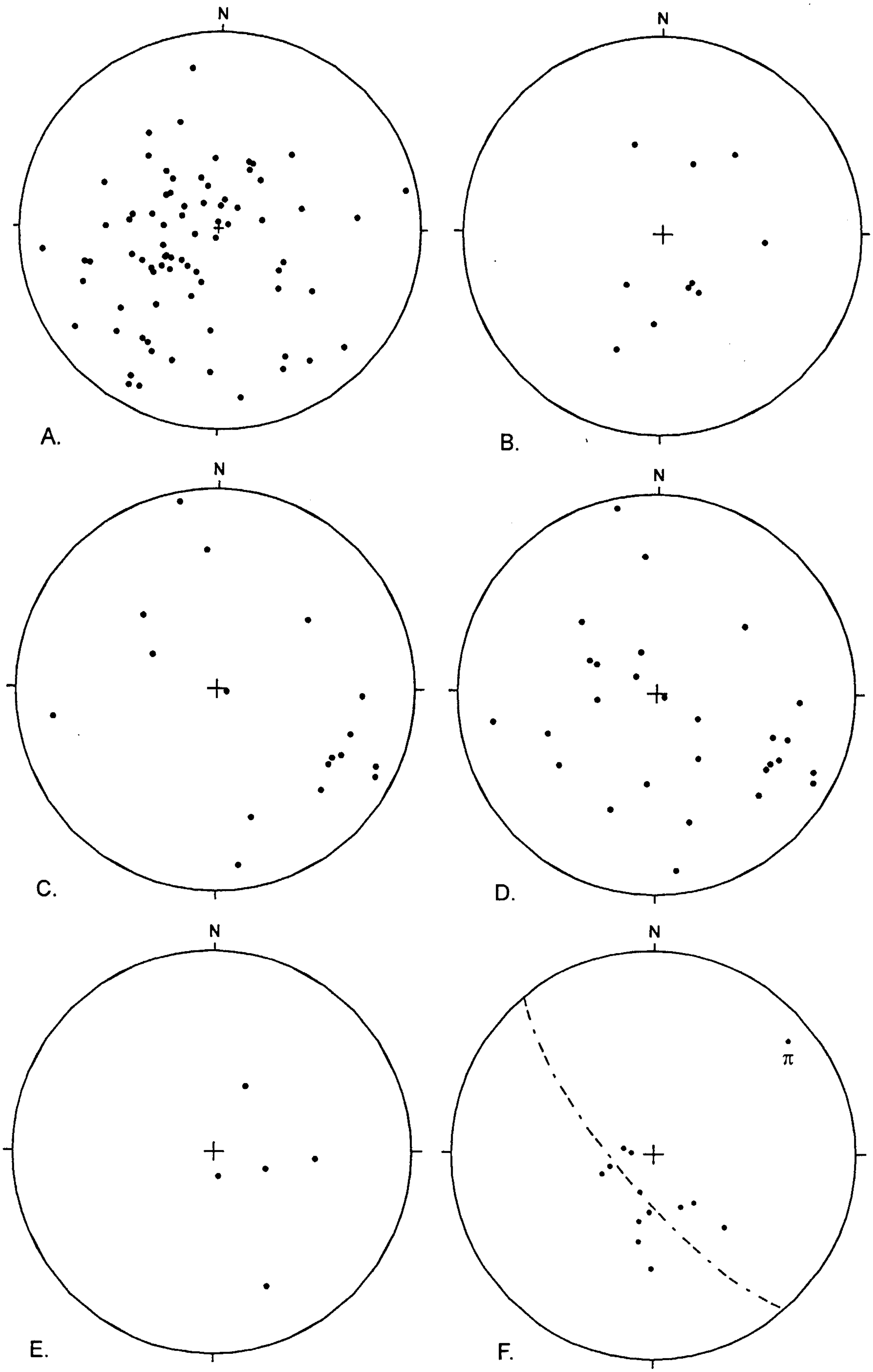

Figure 5. Stereonets for Railroad bedding attitudes. A. All bedding attitudes within study area. B. Domain in the vicinity of the Bald Mountain fault. C. Domain in the vicinity of an antiform on the eastern face of Bald Mountain. D. Domain including all attitudes on the eastern face of Bald Mountain. E. Domain including all attitudes on Copper Bell Ridge. F. Domain in the vicinity of a synform on the northern face of Bald Mountain.

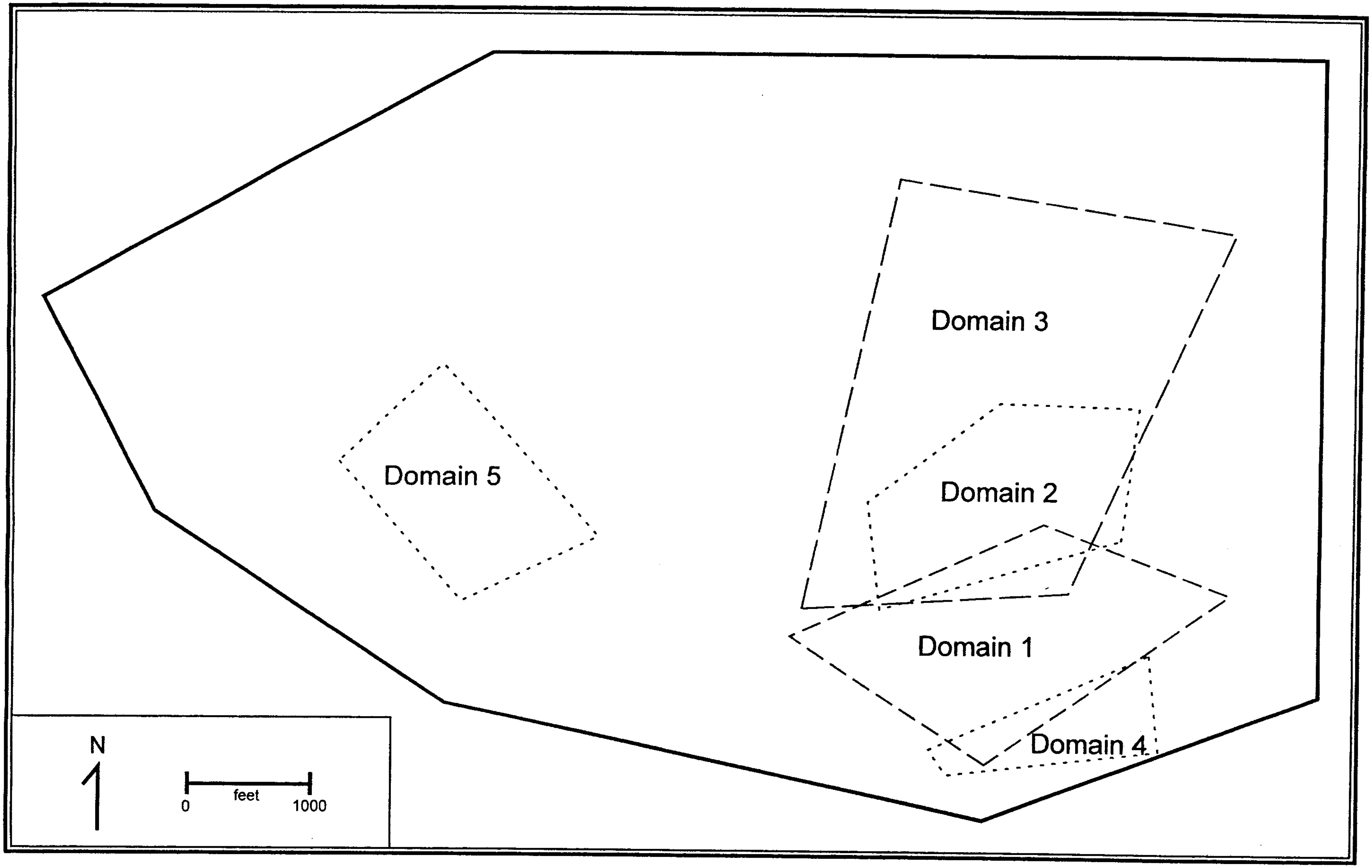

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Figure 6. Structural domains within the study area.

The second structural domain is in the area of a medium scale (less than 100 m but greater than 5 m) antiform that is exposed on the eastern face of Bald Mountain. Seventeen bedding attitudes were plotted on a stereonet for this domain (Figure 5c). Generally, the attitudes cluster as steeply northwest-dipping, northeast-striking beds.

A stereoplot including twenty-eight bedding attitudes was produced for the third structural domain (Figure 5d). This domain covers the entire eastern face of Bald Mountain. Again, the data are widely scattered across the plot and are difficult to interpret.

Copper Bell Ridge is defined as a fourth structural domain (Figure 5e). With only five bedding attitudes, it is difficult to make a meaningful structural interpretation of this area. Generally, the dips are shallow to moderate and to the northwest, with northeasterly strikes.

The final structural domain is the area in the vicinity of a medium scale (less than 100 meters but greater than 5 meters) synform on the north face of Bald Mountain. This fold was observed in the field to plunge approximately N25E to N45E. A pi diagram was constructed in order to statistically define the orientation of this fold (Figure 5f). From the pi diagram, the fold plunges approximately N48E.

Folds

Several small-scale (wavelengths less than 5 meters) to medium-scale (wavelengths from 5 meters to 100 meters) folds are exposed within the study area. Several antiformal folds are exposed on the eastern face of Bald Mountain; one synform (described above) is exposed on the northern face of Bald Mountain. Descriptive terms that are used here for fold orientations and interlimb angles are those proposed by Fleuty (1964).

Small-scale to medium-scale folds are best exposed within the jasperoids and gray siltstones and sandstones on the eastern face of Bald Mountain. These folds are antiformal, upright to steeply inclined, open, and have interlimb angles that range from 80° to 120°. Wavelengths of these folds range from approximately 2 meters to 10 meters, and amplitudes vary from 1 meter to 5 meters. Hinge surfaces of these folds strike moderately northeast to moderately northwest. The dips of the hinge surfaces were not able to be determined due to poor exposure of the folds. The orientations of the hinge lines of these folds were also difficult to determine due to poor exposure.

The synform that is exposed on the northern face of Bald Mountain (discussed above) is defined by changes in bedding attitudes, rather than by good exposure of fold features such as limbs and hinge lines.

Faults

Again, due to the limited extent of outcrops, faults are not exposed within the study area. A large-scale fault, the Bald Mountain fault, was previously mapped by Ketner and Smith (1963) as an eastward trending reverse fault that separates younger rocks to the north from older rocks to the south. This fault is located south of Bald Mountain and north of Copper Bell Ridge. It is not exposed in outcrop; however, the presence of limestone breccias that are cemented by thick, white calcite veins may represent the path of the fault. Additionally, the age discrepancy of the rocks on Bald Mountain and Copper Bell Ridge indicate that a fault is likely present here.

Several splays off of the Bald Mountain fault may cut through Copper Bell Ridge and across the southern portion of Bald Mountain. Indications of these possible splays include changes in topography (specifically, the presence of low saddles on Copper Bell Ridge), and the presence of dikes or gossan zones.

BIOSTRATIGRAPHY

Five samples of calcareous siltstone and limestone were processed at the Biostratigraphic Laboratory at the University of Nevada, Reno for condonts. Samples were collected from the limestones on Copper Bell Ridge, and from limestones and limy siltstones near the eastern and northeastern portions of the map area. There were two reasons for looking for conodonts in these samples. One was to attempt to obtain a firm age for the rocks within the study area, based on biostratigraphy. The second reason involves the uncertainty of whether the jasperoids are the result of silicification of a siltstone protolith or a limestone protolith. If conodonts of similar ages were found in the unsilicified limestones of Copper Bell Ridge and in the other areas that were sampled, then the jasperoids would likely be silicified limestones of the same type as those on Copper Bell Ridge. If the conodonts in these locations had different ages, then another interpretation would be necessary.

Unfortunately, the samples that were processed for conodonts were found to be barren. Only calcite and limonite grains were found in the residues that resulted after processing the rocks for the conodonts. No material resembling organic matter was recovered. The samples had probably been too recrystallized for the microfossils to survive (if they were ever present).

Biostratigraphy has been helpful in this study for a different reason. The limestones from the Devils Gate Formation on Copper Bell Ridge contain intervals of abundant *Amphipora rugosa* fossils. Similar fossils were found in a massive limestone outcrop that is in the northeastern portion of the map area (Figure 4). This massive limestone has been previously mapped as a unit within the Chainman Formation (Will Nordquist, Exploration Mirandor, 1998, personal communication). The fossils within this massive limestone may or may not be *Amphipora rugosa*; however, if they are not *Amphipora rugosa*, then they are a tabulate coral that is not known to have continued into the Mississippian (Calvin Stevens, San Jose State University, 1998, personal communication). Thus, the massive limestone that is present within the northeastern portion of the map area is now mapped as a Devonian limestone for this study.

ALTERATION

Alteration within the study area takes several different forms, depending on the lithology and the location of the rocks. The dominant forms of alteration that have been noted include silicification, argillization, and oxidation. Other hydrothermal alteration products include orpiment and abundant barite.

Silicification at Railroad affects rocks that had calcite-bearing protoliths. The dominant area where silicification has taken place is the eastern face of Bald Mountain. The silicified outcrops are the most prominent exposures in the study area; they tend to have a ribbed appearance, probably from the weathering of less resistant, non-silicified intervals. The silicification is patchy within a given "jasperoid" outcrop. Some portions of the outcrops are silicified and others are not.

Silicification events have occurred at least two times at Railroad. The first event was probably a generally passive silicification of the calcite-bearing protolith. Aphanitic, jigsaw to xenomorphic textures developed during this event. Subsequent brecciation of the jasperoids occurred, and the breccias were later recemented by coarser-grained quartz.

Barite and pyrite introduction are commonly associated with the silicified rocks. Barite is present as coarse-grained, anhedral to subhedral crystals that fill vugs and veins. Commonly, the barite-filled vugs are lined with euhedral quartz crystals. Barite veinlets and veins in jasperoids range in width from 0.003 mm to 3 cm.

Barite veins and vugs are also present in rocks that have not been affected by silicification. Many of the sandstone outcrops throughout the study area have weak to strong barite veining. Barite veins as thick as 1 m are exposed at Copper Bell Ridge; these cut the Devonian dolostones and limestones.

Oxygen and sulfur isotope analysis on barite samples that were collected throughout the study area will be completed. It is hoped that insight regarding the nature of the hydrothermal fluid(s) can be gained from the comparison of the isotopes from these samples. This data will be ready for interpretation in mid-January.

Pseudomorphs of limonite (goethite, hematite, jarosite) after pyrite cubes are common in all rock types at Railroad, with the exception of the granodiorite of the Bullion Stock and the Tertiary volcanic rocks. The cubes range from 0.002 mm to 1 mm. The addition of pyrite at Railroad is likely to be hydrothermal in origin. The common brown to rusty iron oxide staining on the outcrops is due to the abundance of pyrite in this area. The limonite at Copper Bell Ridge is hematite-rich, while the limonite on Bald Mountain tends to be more goethite-rich. Jarosite is not common, though it is locally present.

Argillization has primarily affected the rhyolite porphyry intrusive rocks at Railroad. These rocks have a chalky, bleached appearance due to the abundance of white mica and clay minerals within them. These phyllosilicates have replaced feldspar phenocrysts and groundmass crystals. Common replacement minerals of the feldspars are

	Au	Al	Sb	As	Ba	Be	Bi	Cd	Ca	Cr	Co	Cu	Ga	Ge	Fe	La	Pb	Mg	Mn	Hg	Mo	Ni	P	K	Sc	Ag	Na	Sr	Te	Tl	Ti	W	U	V	Zn
Au (ppb)	1																																		
Al (%)	-0.37	1																																	
Sb (ppm)	*0.88*	-0.4	1																																
As (ppm)	0.29	-0.28	0.33	1																															
Ba (ppm)	0.37	-0.23	0.42	0.45	1																														
Be (ppm)	0.11	0.19	-0.13	-0.08	0.01	1																													
Bi (ppm)	-0.16	-0.24	0.1	-0.08	0.08	-0.08	1																												
Cd (ppm)	-0.08	0.28	-0.08	-0.05	0.03	-0.05	-0.10	1																											
Ca (%)	-0.07	0.3	-0.1	-0.03	0.03	0.08	-0.14	*0.98*	1																										
Cr (ppm)	-0.16	-0.62	0.22	0.20	0.11	-0.18	0.16	-0.05	-0.12	1																									
Co (ppm)	-0.16	0.54	-0.28	-0.18	0.00	0.25	-0.34	0.18	0.28	-0.52	1																								
Cu (ppm)	0.01	0.12	0.06	0.03	0.30	-0.07	0.09	-0.07	-0.12	0.16	-0.13	1																							
Ga (ppm)	0.32	-0.02	0.27	0.23	0.28	-0.05	-0.14	0.03	-0.01	0.30	-0.06	0.29	1																						
Ge (ppm)	-0.16	0.42	-0.2	-0.12	-0.04	0.29	-0.18	-0.08	-0.08	-0.27	0.22	-0.10	-0.07	1																					
Fe (%)	-0.02	-0.25	-0.06	-0.04	0.24	-0.04	-0.02	-0.05	-0.08	0.10	-0.11	-0.02	-0.04	-0.07	1																				
La (ppm)	-0.14	0.15	-0.19	-0.06	-0.20	0.24	-0.38	0.03	0.09	-0.32	0.40	-0.27	-0.20	0.55	-0.24	1																			
Pb (ppm)	0.1	-0.14	-0.08	-0.08	0.26	-0.04	0.63	-0.08	-0.09	0.05	-0.11	0.10	0.10	-0.12	-0.05	-0.31	1																		
Mg (%)	0.15	0.05	0.14	0.14	0.25	0.17	-0.41	0.22	0.33	-0.41	0.48	-0.15	0.08	-0.03	0.03	0.39	-0.21	1																	
Mn (ppm)	0.21	0.44	-0.32	-0.11	-0.03	0.27	-0.27	0.34	0.45	-0.46	*0.88*	-0.19	-0.09	-0.02	-0.10	0.24	-0.09	0.48	1																
Hg (ppm)	*0.78*	-0.38	0.63	0.55	0.51	-0.12	-0.20	-0.10	-0.10	0.13	-0.18	0.17	0.50	-0.18	-0.04	-0.08	-0.01	0.20	-0.20	1															
Mo (ppm)	-0.11	0.27	-0.15	-0.08	-0.11	-0.07	0.03	-0.05	-0.03	0.13	0.20	0.44	-0.04	-0.11	-0.04	-0.09	0.01	-0.28	0.05	-0.17	1														
Ni (ppm)	0.11	0.52	0.01	-0.14	-0.02	0.28	-0.32	0.47	0.46	-0.31	0.49	-0.08	0.01	0.43	-0.08	0.28	-0.18	0.08	0.44	-0.04	-0.08	1													
P (ppm)	-0.27	0.31	-0.33	0.26	0.17	0.25	-0.04	0.20	0.30	-0.19	0.44	0.31	-0.23	0.06	-0.13	0.31	-0.07	0.24	0.48	-0.14	0.40	0.18	1												
K (%)	0.16	-0.57	0.15	0.06	-0.07	-0.03	-0.23	-0.13	-0.10	0.10	0.02	-0.40	-0.07	0.02	0.05	0.52	-0.24	0.51	0.01	0.17	-0.47	-0.12	-0.11	1											
Sc (ppm)	-0.29	*0.71*	-0.28	-0.13	-0.30	0.34	-0.08	0.32	0.39	-0.35	0.44	0.00	-0.09	0.20	-0.15	0.18	-0.22	-0.03	0.37	-0.37	0.45	0.41	0.42	-0.49	1										
Ag (ppm)	0.35	-0.31	0.40	0.11	0.44	-0.20	0.48	0.01	-0.06	0.38	-0.39	0.60	0.16	-0.29	-0.06	-0.42	0.51	-0.28	-0.38	0.21	0.20	-0.14	0.11	-0.25	-0.24	1									
Na (%)	-0.09	0.22	-0.10	-0.08	-0.04	-0.06	-0.11	*0.98*	*0.96*	-0.05	0.14	-0.11	-0.03	-0.09	-0.07	0.09	-0.09	0.20	0.29	-0.14	-0.06	0.44	0.20	-0.05	0.31	0.01	1								
Sr (ppm)	0.21	-0.25	0.21	0.31	0.28	0.10	0.01	0.03	0.03	0.12	-0.13	0.02	-0.03	0.03	0.04	0.31	-0.06	0.00	-0.13	0.27	-0.11	0.20	0.32	0.16	0.06	0.29	0.09	1							
Te (ppm)	0.01	-0.38	0.31	0.04	-0.01	-0.14	0.38	-0.11	-0.13	0.44	-0.35	0.21	-0.01	-0.20	-0.08	-0.07	0.02	-0.01	-0.31	-0.16	0.03	-0.31	0.03	0.23	-0.17	0.39	-0.05	0.03	1						
Tl (ppm)	*0.89*	-0.24	*0.78*	0.13	0.25	-0.07	-0.16	-0.05	-0.04	-0.07	-0.05	-0.11	-0.03	-0.08	-0.03	-0.06	-0.06	0.18	-0.12	0.60	-0.07	0.20	-0.18	0.17	-0.19	0.24	-0.06	0.24	-0.09	1					
Ti (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1				
W (ppm)	0.07	-0.05	0.01	-0.02	-0.19	-0.07	-0.02	-0.08	-0.09	0.14	0.02	0.06	-0.06	-0.06	-0.07	0.24	-0.16	-0.23	-0.07	-0.01	0.38	0.14	0.29	-0.01	0.33	0.20	0.00	*0.72*	0.00	0.15	0.00	1			
U (ppm)	-0.09	0.15	-0.20	-0.13	-0.18	-0.07	-0.02	-0.06	-0.09	0.37	0.07	0.35	0.14	-0.12	0.08	-0.28	0.03	-0.47	0.04	-0.10	*0.72*	0.10	0.09	-0.46	0.20	0.14	-0.10	-0.09	-0.13	-0.13	0.00	0.38	1		
V (ppm)	-0.08	0.26	-0.03	0.09	-0.09	0.19	-0.20	0.01	0.03	-0.11	0.06	-0.06	0.06	0.62	-0.04	0.35	-0.22	-0.01	0.03	-0.10	-0.07	0.14	0.11	-0.05	0.23	-0.20	-0.02	0.01	0.09	-0.10	0.00	-0.11	-0.22	1	
Zn (ppm)	-0.05	0.38	-0.09	-0.06	0.06	-0.01	-0.14	*0.97*	*0.96*	-0.12	0.33	-0.04	0.01	0.00	-0.07	0.06	-0.06	0.22	0.45	-0.12	-0.01	0.58	0.29	-0.17	0.38	0.00	*0.94*	0.04	-0.15	-0.02	0.00	-0.07	-0.02	0.03	1

Table 1. Correlation matrix for geochemical data from 31 rhyolite intrusive samples from Railroad. Italicized values are greater than 0.70.

illite, sericite, kaolinite, and smectite. It is likely that these rhyolite porphyries have been affected by hydrothermal alteration, since pseudomorphs of limonite after pyrite are locally common, but some of the argillization may be the result of weathering at the surface.

GEOCHEMISTRY

Samples from thirty-one rhyolite porphyry dike and sill outcrops were collected. Chemex Laboratories completed a thirty-five element analysis on these samples. From the raw data provided by Chemex, a correlation matrix was created in an effort to understand which elements are related to each other (Table 1). Data for elements that have a correlation of greater than 0.70 were plotted as scatterplots (Figure 7a through 7k). Interpretation of these data has not yet been completed, so only preliminary results are given here.

Zn, Ca, and Cd have a high correlation with each other. Ca and Cd have a correlation of 0.98 (Figue 7a.) and Zn and Cd have a correlation of 0.97 (Figure 7b). Ca and Zn have a correlation of 0.96 (Figure 7c).

Tl and Au have a correlation of 0.89 (Figure 7d). The occurrence of Au is also related to the occurrence of Sb (0.86 correlation) and to the occurrence of Hg (0.78 correlation) (Figures 7e and 7f). Not surprisingly, Tl and Sb also have a good correlation (0.76) (Figure 7g).

Other related elements include Mn and Co (0.88 correlation), Sr and W (0.72 correlation), U and Mo (0.72 correlation), and Sc and Al (0.71 correlation) (Figures 7h through 7k).

Additional geochemical data from rock chip and soil samples from throughout the study area was provided by Kinross Gold in mid-December. These data will be interpreted and displayed as contour maps at a later time.

FUTURE WORK

Though much work has been done so far on this project, a good deal of work still needs to be done in the coming months. During the remainder of this winter, structural

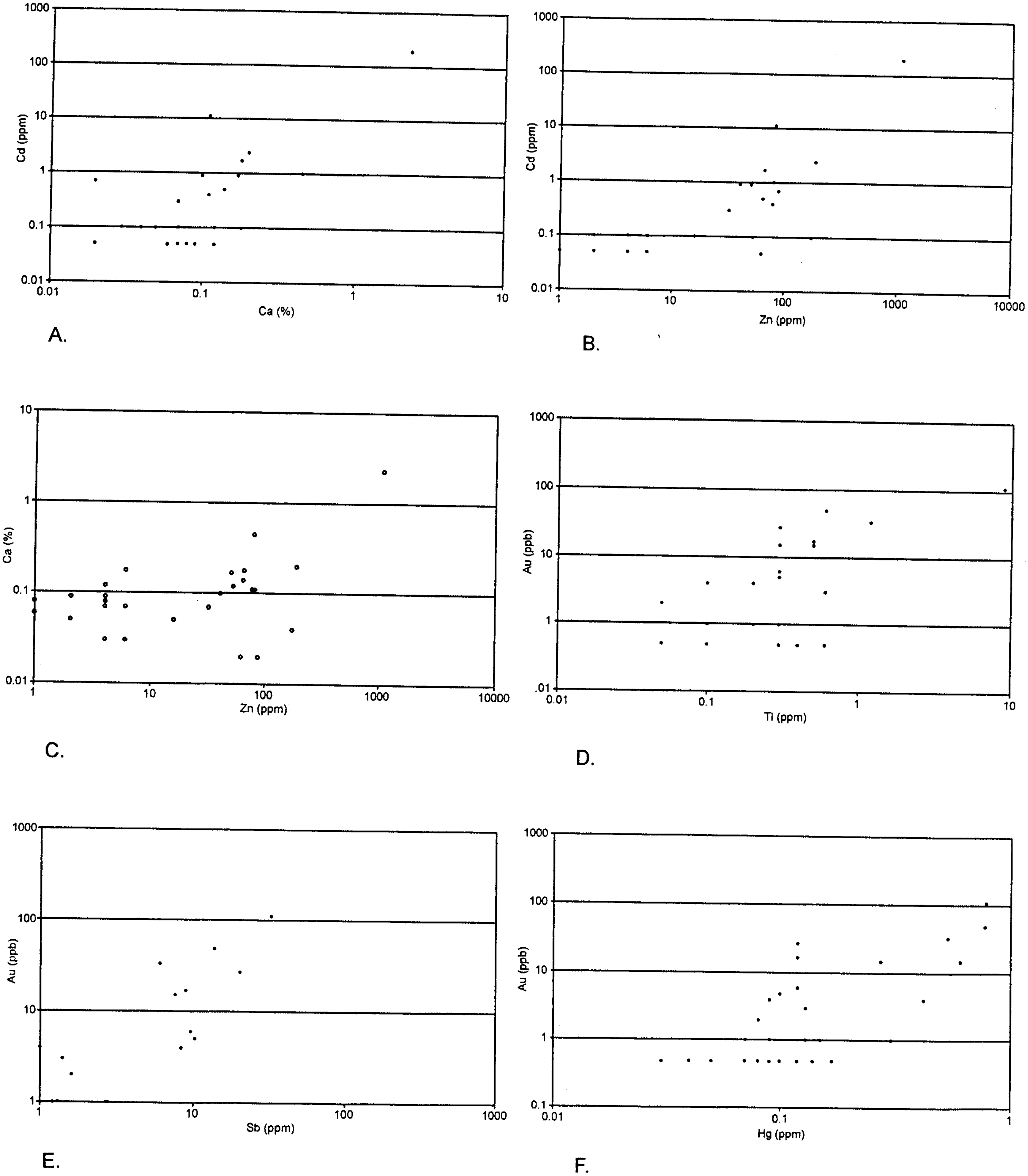

Figure 7. Scatterplots of geochemical data from 31 rhyolite porphyry samples from the Railroad district. A. Ca vs. Cd, B. Zn vs. Cd, C. Zn vs. Ca, D. Tl vs. Au, E. Sb vs. Au, F. Hg vs. Au, G. Tl vs. Sb, H. Mn vs. Co, I. Sr vs. W, J. U vs. Mo, K. Sc vs. Al. 7G. through 7K. are on the following page.

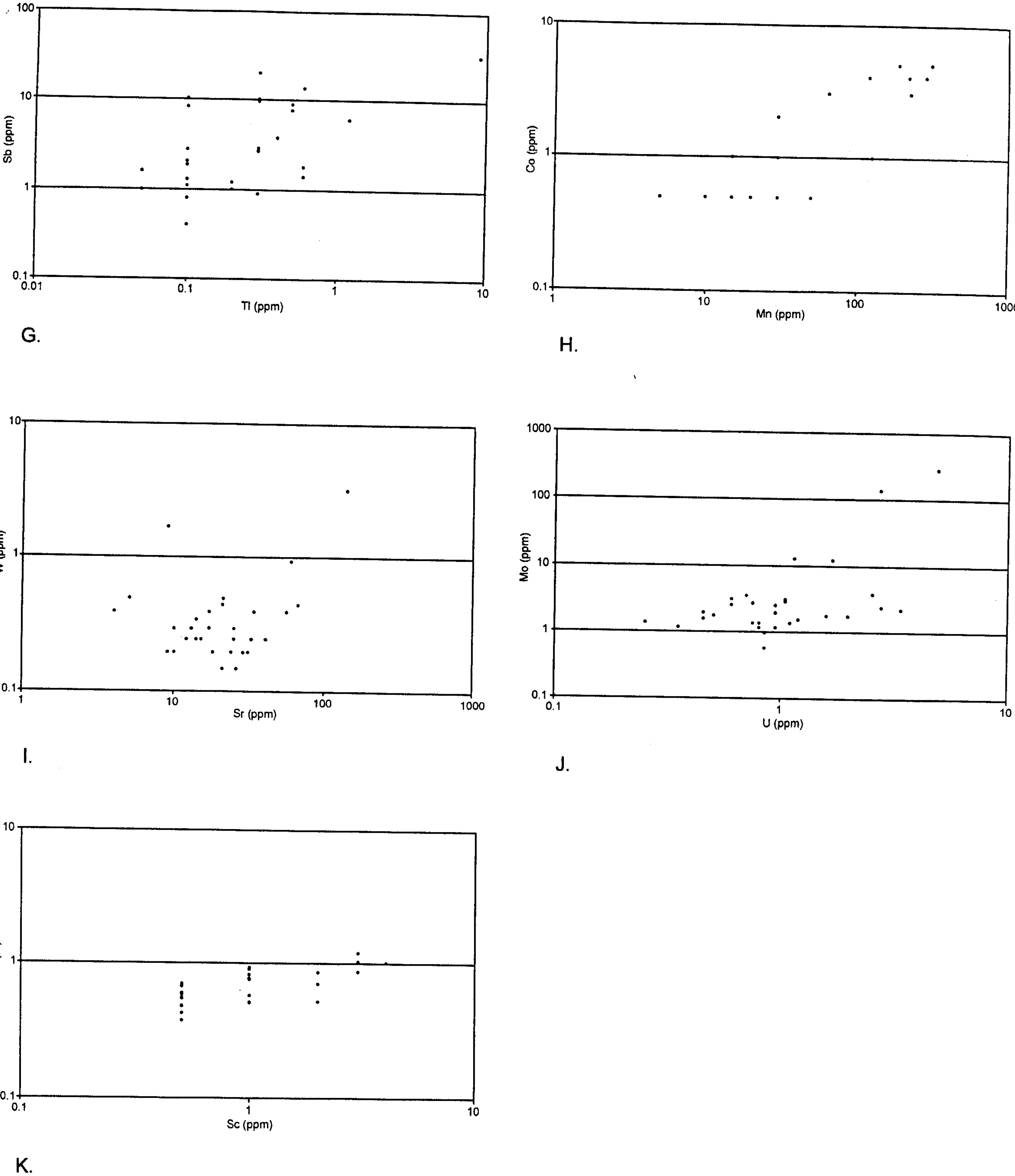

Figure 7, continued.

interpretations, including detailed cross sections, will be made. Interpretation of all geochemical data will be completed, and these data will be displayed as contour maps. Barite isotope data should be available in mid-January for interpretation. By March, when interpretations of structure, geochemistry, and isotopes are completed, thesis writing will commence.

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